

## FLEXIBLE MATERIAL INCLUDING CONTROLLED SUBSTANCE RELEASE

The invention relates to wearable electronics and the controlled release of substances.

5        Microencapsulation technology involves encapsulating small amounts of substance, such as perfume, in plastic, gelatin, or polymer spheres that are a few microns in diameter. The spheres release the substance upon rupturing. Rupturing occurs either mechanically (i.e. by scratching with a fingernail or pulling apart adhesives on either side of the spheres), chemically (i.e., by dissolving the spheres in a solvent to enable release of the substance),  
10    or thermally (i.e., by heating the spheres with an external source above their melting points to initiate rupturing). A variety of substances can be encapsulated in microcapsules. As an example, the substance can be a fragrance, a dye, a lotion, or oil. Substances can be contained in microcapsules for as long as several years.

Conventionally, use of microcapsules has been limited to scent inserts in magazines  
15    and commercially available "scratch-and-sniff" merchandise, both of which are relatively inflexible.

United States patent number 4,990,392 (the "'392 patent"), herein incorporated by reference, describes a textile product that includes microcapsules applied to the fabric using thermo-adhesive materials. The '392 patent describes adding microcapsules  
20    containing substances to a textile such that the microcapsules will withstand washing and other normal uses of the textile. The microcapsules rupture during ordinary use of the textile either due to a rise in temperature or an increase in pressure. However, the release of substances contained in the microcapsules cannot be selectively controlled.

Fabrics including conductive fibers are also commonly known in the art. Such  
25    fabrics include fibers interwoven with textile fibers to create circuits. Current can be

selectively passed to an area on such fabric using a switch and a power source. Fig. 1 depicts a garment 2 that includes conductive fibers. Garment 2 has three current paths 3, 3', 3'' that are made up of conductive fibers through which current can be passed from power source 4. Current paths can also be formed using other known techniques such as  
5 conductive ink. Garment 2 also includes a switch 5 that the wearer of the garment can select which current path he or she chooses. For example, a user can attach a portable electronic device, such as a cellular telephone or portable radio, to garment 2 at clip 6. When the wearer sets switch 5 to power the electronic device, current passes from power source 4 through current path 3'' to clip 6 and into the attached device. The conductive  
10 fibers that make up current paths 3, 3', and 3'' can also be selected to have a high resistance. Consequently, they act as resistors and release electrical energy as heat. Current paths 3, 3', and 3'' can be used to heat garment 2 in selected areas. However, these fabrics are not used to selectively control the release of a substance from within the fabric itself.

15 Accordingly, it would be desirable for a flexible fabric to include a means for selectively controlling the release of a substance that does not suffer from the prior art limitations.

A flexible material including several elements meets the need for a flexible material that allows for the controlled release of a microencapsulated substance in one aspect. One  
20 element is interwoven fibers. A second element is means for passing a current and generating localized heating interspersed among the fibers. A third element is at least one microcapsule, situated on or within the interwoven fibers and means for passing a current, containing a substance and releasing said substance upon rupture due to localized heating generated by selectively heating the means for passing a current. A fourth element is a

means for controlling the current passed through the means for passing a current to enable controlled localized heating.

In one embodiment, the means for passing a current and generating localized heating is conductive fibers. In another embodiment, the means for passing a current and  
5 generating localized heating is conductive ink.

In yet another embodiment, the at least one microcapsule further comprises a thermo-plastic polymer. In another embodiment, the thermo-plastic polymer forms the at least one microcapsule containing the substance to be released.

In yet another embodiment, the at least one microcapsule releases the substance  
10 upon reaching its melting point. In another embodiment, the substance has a lower vapor point than the melting point of the at least one microcapsule.

In yet another embodiment, the substance is an oil, liquid, or solid material. In another embodiment, the substance generates a scent upon release into the ambient environment.

15 In still another embodiment, the means for controlling the current includes a power source and a current path selector. In another embodiment, the means for controlling the current further includes at least one programmable sensor which determines when to activate and deactivate the means for passing a current. In another embodiment, the at least one programmable sensor senses when a predetermined number of microcapsules  
20 have ruptured. The means for controlling the current can also include a timer. In one embodiment the timer determines when to deactivate the means for passing a current based upon the melting point of the at least one microcapsule, the number of microcapsules, and the material properties of the substance contained in the at least one microcapsule.

In another embodiment, the flexible material includes multiple microcapsules a first  
25 portion of which contain a first substance and a second portion of which contain a second

substance. In another embodiment, the first substance and the second substance have different material properties. The different material properties can be scent, melting point, viscosity, physical state, color, flavor, chemical composition, and texture. In another embodiment, the first portion of microcapsules containing the first substance are grouped  
5 on or within an area of the flexible material such that the means for controlling the current locally heats the area and enables the release of the first substance. In another embodiment, the means for controlling the current allows local heating of either the first or the second portion of microcapsules and controllably enables the release of the first or second substance.

10 In still another embodiment, the means for controlling the current allows local heating of both the first and the second portion of microcapsules and controllably enables the release of a portion of the first and second substances.

In another embodiment, the first portion of microcapsules has a different melting point than the second portion of microcapsules.

15 In another embodiment, the means for controlling the current includes means for locally heating the first and second portion of microcapsules such that only the first portion of microcapsules rupture and release the substance they contain.

In one aspect a flexible material includes interwoven fibers; means for passing a current and generating localized heating interspersed among the fibers; at least one  
20 substance, situated on or within the fibers and means for passing a current, that vaporizes due to localized heating generated by selectively heating the means for passing a current; and means for controlling the current passed through the means for generating localized heating.

In another aspect of the invention, a method of controllably releasing a substance  
25 contained in a flexible material includes several steps. One step is integrating fibers and

means for passing a current and generating localized heating interspersed among the textile fibers. Another step is forming at least one microcapsule containing a substance. Another step is incorporating the at least one microcapsule above or within the integrated fibers and means for passing a current. Another step is selectively heating the at least one  
5 microcapsule. Another step is rupturing the at least one microcapsule, and another step is releasing the substance.

In another aspect of the invention, a method of controllably releasing a substance contained in a flexible material includes integrating fibers and means for passing a current and generating localized heating interspersed among the textile fibers; forming a substance  
10 above or within the interwoven textile fibers and means for passing a current; selectively heating the substance; and evaporating the substance.

The invention provides many advantages that are evident from the following description, drawings, and claims.

The invention may be more completely understood in reference to the following  
15 figures:

Fig. 1 depicts a prior art garment including conductive fibers;

Fig. 2 depicts a cross section of a flexible material including conductive fibers and microencapsulated substances;

Fig. 3 depicts a garment including conductive fibers and multiple zones of  
20 microencapsulated substances;

Fig. 4 depicts a cross section of an area on a flexible conductive material with microencapsulated substances in separate zones on its surface; and

Fig. 5 depicts another embodiment of a flexible conductive material with microencapsulated substances in separate zones on its surface.

Fig. 2 depicts a cross section of a flexible material including conductive fibers and microencapsulated substances. The flexible material includes conductive fibers 23 made of a conductive material and woven into textile fiber layers 20. Conductive fibers 23 are covered on both sides by insulating layers 22 which prevent microcapsule layers 21a and 21b from overheating or heating too quickly. Layers 21a and 21b are composed of microcapsules containing a substance, for example perfume. When current is passed through conductive fibers 23, they act as resistors and give off a fixed amount of heat. This heats insulating layers 22 and microcapsule layers 21a and 21b. As individual microcapsules begin to heat, the perfume they contain reaches its vapor point. As individual microcapsules reach their melting points, they rupture and release the vaporized perfume.

Insulating layers 22 can be selected to ensure that only a limited amount of heat will reach the microcapsules so that a limited number of microcapsules will break each time a user passes a current through conductive fibers 23. This allows the flexible material to be used multiple times since only a few microcapsules are broken during each usage. The insulating layers can also exist as coatings surrounding conductive fibers 23. Additionally, the amount of current passed through conductive fibers 23 can also be set to achieve the desired amount of microcapsule breakage. The desired number of microcapsules to be broken during a single usage depends upon the material properties of the substances they contain. For example, if the microcapsules contain a concentrated strong fragrance, only a few need be broken in a single use.

In Fig. 2, microcapsule layers 21a and 21b can also be composed of microcapsules containing different substances. For exemplary purposes, assume that the flexible material is part of a garment. As such, layer 21a is closer to the ambient environment and layer 21b is closer to the skin of the wearer. The microcapsules in layer 21a can contain perfume,

since the substance of perfume should have sufficient exposure to the ambient environment. The microcapsules in layer 21b can contain skin lotion, since the release of lotion should occur closer to the wearer's skin.

Fig. 3 depicts a garment 2 made of a flexible material that includes conductive fibers and multiple zones of microencapsulated substances. Here a user can set controller 50 to either activate zones 30, zone 31 or to power device clip 6 from power source 4. Zones 30 contain, for example, microencapsulated deodorizing antiperspirant. Since these zones are situated in proximity to a user's armpits, the user can activate these zones such that the microcapsules therein are ruptured and provide for the release of deodorizing antiperspirant. In addition, zones 30 can contain sensors which signal controller 50 to generate current in zones 30 when they sense deodorizing or perspiring occurs. The sensors can also dictate when controller 50 should deactivate zones 30, i.e., when a certain amount of microcapsules have ruptured, or when the sensors no longer detect order or perspiring. Further, controller 50 can also be programmed to shut off current to zones 30 automatically after a preset period of time determined by the melting point and/or the number of microcapsules in zone 30. The sensors can be any type of biosensor, chemical sensor, or mechanical sensor known in the art.

Zone 31 contains, for example, at least one fragrance. If the wearer of garment 2 wishes to alter the scent of the ambient environment, he or she can set controller 50 to activate zone 31. Activation will pass current from power source 4 through current path 3''' to zone 31. The conductive fibers in zone 31 heat up such that a portion of the microcapsules in zone 31 rupture and release fragrance. Controller 50 can automatically shut off current to zone 31 after a preset period of time based on the melting point of the microcapsules in zone 31 as well as the material properties of the substance contained in the microcapsules. For example, controller 50 can be programmed to generate current for

30 seconds to zone 31 because the rate at which the microcapsules in zone 30 rupture would release ample fragrance to comfortably alter the user's immediate environment in that period of time. Further, a user can manually set controller 50 based on their own personal preference.

5 Garment 2 is manufactured such that the microcapsules and conductive fibers in zones 30 and 31, as well as conductive fibers in current paths 30, 30', 30'', and 30''' can be washed with other garments without breaking any microcapsules or affecting any conductive fibers. In addition, garment 2 can include enough microcapsules in a given zone to allow for a certain number of uses. As an example, zone 31 can contain enough  
10 microcapsules that the fragrance contained therein can be released 600 times at 30 seconds of current per activation. Thus, garment 2 has a defined useful life determined based upon the number of microcapsules in an area, the rate at which they rupture, the amount of time they are heated, and the melting point of the microcapsules. A further advantage is that even when garment 2 achieves its useful life in terms of zones 30 and 31, it can still be  
15 worn as a garment. Further, Garment 2 can still support portable electronic devices by passing current from power source 4 through current path 3'' to clip 6 onto which a device can be attached and powered. Garment 2 can be any type of garment worn by a user and is not limited to the shirt depicted in Fig. 3. Further, any type of flexible material can include zones such as zones 30 and 31.

20 Fig. 4 depicts a cross section of a layer of flexible material, for example, zone 31. In Fig. 4, strips of different microencapsulated substances 42, 43, 44 are deposited above conductive areas 40. As an example, a user can set controller 50 to generate a fragrance that is composed of 2 parts substance 44 and one part substance 42. Controller 50 passes current through current paths that heat up the conductive fabric areas 40 under strips  
25 corresponding to microencapsulated substances 42, 44, 44. Insulators 41 prevent adjoining



strips from being heated. Thus within a given zone, multiple substances can be simultaneously and controllably released.

Controller 50 can be programmed with the relative proportions of each strip needed to produce a given result, such as a given coloration or fragrance. Thus, when a user  
5 selects the given coloration or fragrance, controller 50 will automatically pass current from power source 4 through the appropriate current path to heat the appropriate conductive areas 40 to cause the requisite proportions of substance to be released due to microcapsule rupture.

In addition, strips corresponding to substances 42, 43, 44 can be formed from  
10 microcapsules with different melting points for each different substance 42, 43, 44. Thus, conductive areas 40 can all be heated simultaneously and based on the different melting points of the microcapsules, different proportion of substances 42, 43, 44 can be released.

Depositing substance directly onto zone 31 can also form strips corresponding to substances 42, 43, 44. In other words, conductive areas 40 can selectively heat substances  
15 42, 43, 44 to either liquefy, evaporate, or sublime and cause the same result as if substances 42, 43, 44 were microencapsulated.

Fig. 5 depicts a matrix arrangement of zone 31, whereby controller 50 can selectively activate sub-zones 42, 43, 44 according to the user's desired effect. Each sub-zone 42, 43, 44 is independently controllable such that controller 50 can pass current from  
20 power source 4 through a current path to a conductive area 40 below a given sub-zone and heat only the desired sub-zone.

The preceding expressions and examples are exemplary and are not intended to limit the scope of the claims which follow.